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AD-A210 176

209700-2-T

Technical Report

DISTRIBUTION OF PROCESSING TASKS FOR THE REMIDS II REAL-TIME PROCESSOR SYSTEM

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JUNE 1989

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a REPORT SECURITY CLASSIFICATION	1b RESTRICTIVE MARKINGS
Unclassified	None

2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	Unlimited Distribution

4 PERFORMING ORGANIZATION REPORT NUMBERS(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
209700-2-T	

6a NAME OF PERFORMING ORGANIZATION	6b OFFICE SYMBOL (if applicable)	7a NAME OF MONITORING ORGANIZATION
ERIM		U.S. Army Belvoir Res & Dev. Ctr. Countermine Technology Division

6c ADDRESS (City, State, and ZIP Code)	7b ADDRESS (City, State, and ZIP Code)
P.O. Box 8618 Ann Arbor, MI 48105	Fort Belvoir, VA 22060

8a NAME OF FUNDING /SPONSORING ORGANIZATION	8b OFFICE SYMBOL (if applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
U.S. Army Belvoir Research & Development Ctr.		DAAK 70-88-C-0032

8c ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS			
	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO
Ft. Belvoir, VA 22060				

11. TITLE (Include Security Classification)

Distribution of Processing Tasks for the REMIDS II Real Time Processor System

12. PERSONAL AUTHOR(S)

R. Horner

13a TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Technical	FROM_____TO_____	1989 June 1	7

16. SUPPLEMENTARY NOTATION

17 COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The allocation of processing tasks within the REMIDS II System is described. A time-line of the multiprocessing activities serves to develop a set of requirements for communications and control. Unresolved algorithm and operational issues are identified and define areas for further study.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	Uncl.

22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code)	22c OFFICE SYMBOL
R. Horner	994-1200	

DD Form 1473, JUN 86   Previous editions are obsolete.
ERIM ··· 6

Distribution of Processing Tasks for the
REMIDS II Real-Time Processor System

The demonstration system must perform many different operations to successfully locate minefields in real time. These operations fall into the categories of:

- Scanner data input
- Scanner data processing
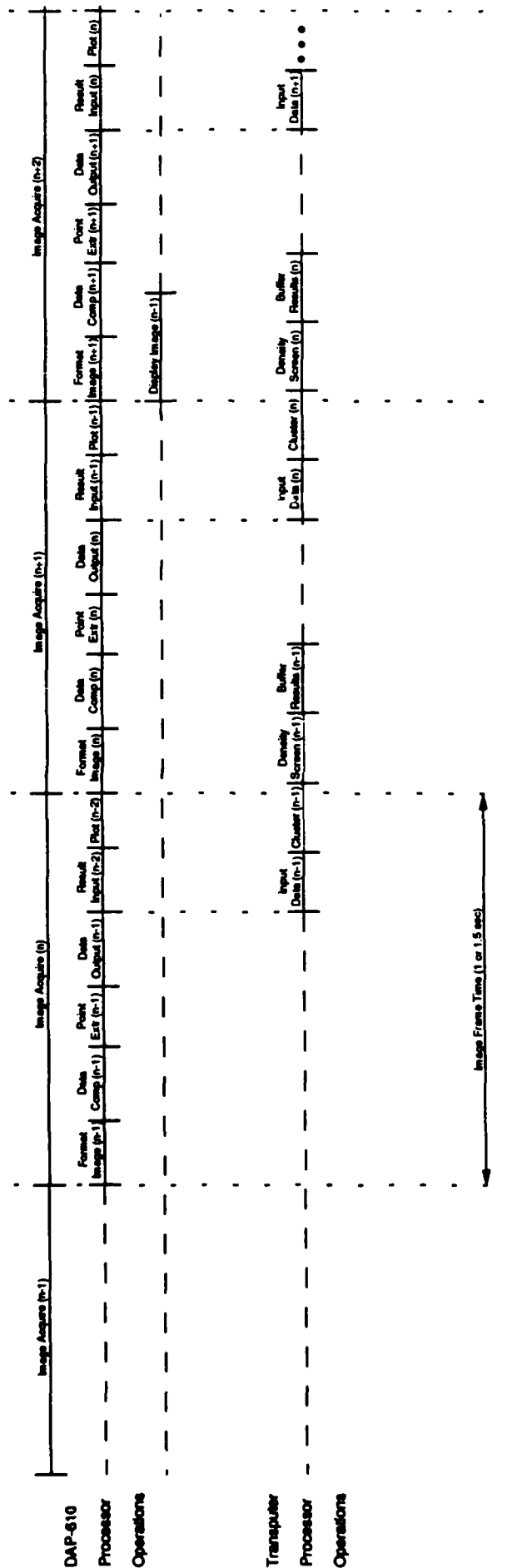- Inter-processor communication
- Display data output

The time-line in Figure 1 illustrates ERIM's current view as to what operations are required and in which processor (DAP or Transputer) they should be implemented.

The time-line also provides an overall view of the operations from which system-level requirements may be derived. For instance it shows three parallel processes occuring concurrently on the DAP-610. Support of this concurrent processing from AMT would be necessary to keep program development costs down. Also there is a three-image-acquisition aperture time delay between first starting to acquire a scanner image and having results ready to display. This implies three images must be buffered in the DAP-610 in addition to any temporary storage needed for the algorithm execution. Finally, the time-line indicates a "framing" image display. Any additional computations for a scrolling display (vertical decimation, image shifting) would have to be distributed in time during the other processing and would have to be repeated at least ten times per second (preferrably 30 times per second) to attain a smooth scroll appearance.

The following sections examine each operation category from above and describes the operations it contains. At points of communication, the data-rates expected are indicated as well as the expected method and controlling processor of the communication. Also Section 5.0 will discuss system/algorithm implementation issues that were not even tentatively resolved during or before the time-line was generated.

1.0 Scanner Data Input Operations

These operations receive the raw data from the scanner, de-multiplex the channel data, select the three desired channels, separate the house keeping from image data, and place

Figure 1 – Remids Real-Time Processor Time-Line

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the three images in buffers for further processing. All of these operations will be completed by custom input hardware or software in the DAP-610. These operations correspond to the top line of DAP processor operations plus the *Format Image* operation in the middle of the time-line in Figure 1. The raw data from the scanner is assumed to be double buffered to accomodate the continuous flow from the scanner. The final three formatted images may be single buffered since they will not be needed after data compression processing except for display (see Section 4.0).

During these operations the DAP will communicate with the Daedalus REMIDS II scanner pre-processor to obtain the scanner data. ERIM understands that Daedalus will provide AMT with the specification for the input data format. The data rate is currently $\approx$ 3.3 MBytes per second with the scanner pre-processor as the driver of the data transfers. The exact division of the operations between input hardware and the DAP array processor has not been set by AMT, but ERIM anticipates that at least some of the operations will be implemented in the DAP array using software.

2.0 Scanner Data Processing Operations

These operations constitute a real-time implementation of WES's pre-existing algorithms for locating mines in the scanner image data. These operations cover the *Data Comp* operation in the DAP operations and the *Cluster* and *Density Screen* operations in the Transputer operations parts of the time-line in Figure 1. The algorithms are broken into two roughly equal halves; Data Compression and Classification. ERIM's view of these algorithm is based on source code supplied by WES and is described in detail in the report " Remote Minefield Detection System Real-Time Processing Architecture Study", ERIM document number ERIM-208600-1-T.

A summary of the algorithms will define ERIM's view of software load on each machine. The algorithms process the three channels of imagery input from the Daedalus scanner. The Data Compression algorithm thresholds the images and applies edge-detection operations and object-sizing tests. All pixels passing these tests are extracted from the images together with their (x, y) coordinates, and this list is passed to the Classifier. The Classifier uses the pixel values from all three channels to multi-spectrally cluster the points (pixel value trios) and identify different "classes" of materials in the images. The class tags along with the image (x, y) coordinates of the points are used to reconstruct spatial objects from the

clustered points. These objects are then subjected to size and spatial density tests. The survivors of these tests are assumed to be mines, and the locations of the individual objects (mines) in each class are output to graphically tag the mine location in an image displayed to the operator.

The two halves of the algorithm will run on separate hardware, in parallel, as shown in Figure 1. The data compression algorithm computes a list of points that has been assumed to total less than 5000 elements for a 512-line image frame size. Two 32-bit words are required for each point, giving an output data-rate of $\approx$ 27000 bytes per second. The classifier computes a list of object coordinates (assumed maximum of 1000) that would require one 32-bit word for each element, or a worst case data-rate of $\approx$ 2700 bytes per second. ERIM assumes that the DAP performs the actual movement of data between the two systems. This communication will be examined more closely in Section 3.0.

3.0 Inter-Processor Communication Operations

The two halves of the real-time processor cooperate to complete the necessary algorithms in time with the scanner input. The communication software necessary for this cooperation covers the *Data Output* and *Result Input* parts of the DAP operations and the *Input Data* and *Buffer Results* parts of the Transputer operations time-lines. ERIM anticipates a shared memory, mailbox type interface using memory addressable by both processors over the VMEbus. The mailbox software must be carefully implemented to prevent time-dependent problems. Support from AMT for this type of coding may be necessary.

ERIM has assumed the following sequence on the DAP:

1. Poll data compression output-buffer-flag to be sure the Classifier has read the old data;

2. Write data compression output list to shared memory buffer and set the flag indicating new data is available;

3. Poll a second flag indicating Classifier results are buffered and waiting for pickup;

4. Move data to private buffer and reset result flag.

A similar sequence with the buffer meanings (input/output) reversed would be implemented on the VME-based transputer. Time-out mechanisms will also be needed to allow system recovery and resynchronization in the case of intermittent hardware failure.

4.0 Operator Display Operations

These operations process the results of the classification and display an image to the operator indicating the locations of the identified mines. These operations include the *Plot* and *Display Image* parts of the DAP time-line of Figure 1. Some sort of graphics operation would be used to tag the mine locations, in color, in a buffered copy of one of the original scanner channels from which the result were derived. This tagged image would then be sent to the DAP display buffer board for viewing by the operator. Possibilities for the graphics operation include drawing different colored shapes, or changing the pixel-values so that they appear in color on the operator's monitor.

Several technical issues crop up with the display. Displaying mine 'tags' on top of an old (three acquisition times prior) image, requires circularly (FIFO) buffering copies of the image to be overlaid with mine information. If the number of input image frame lines is smaller than the number of display lines, or if vertical decimation is used, multiple frames of images must be combined into a single display-image. Finally, the hardware and software of the DAP must handle display operations concurrent with image input from the scanner.

5.0 Unaddressed Algorithm Issues

This section is a catch-all to discuss issues that ERIM did not feel we could reasonably decide. These issues are:

- Processing continuous (real-time) data
- Scoring of mine classes
- Input image frame size
- Scrolling vs. paging display
- Graphics presentation to operator
- Operator input effects on the algorithms

These issues will be described in the following paragraphs together with ERIM's view of the problems.

The algorithms provided to ERIM for study presupposed a frame-by-frame division of the input data that did not retain any knowledge of previous frame's results for use in future processing. The clustering algorithm in particular could benefit from maintaining class clusters across several minutes of input data. This raises the question of how to eliminate stored data as it ages and becomes less useful. ERIM does not currently have any specific solutions to these issues. Further study and discussions with WES are needed.

The mine(field) class information generated by the Classifier should be ranked or scored before viewing by the operator. Only the highest scoring classes would be displayed to the operator as potential minefields. The scoring allows for graceful degradation of the real-time system if the terrain yields a large number of false alarms. The derivation of a score for each class was not contained in the source-code provided to ERIM. If a satisfactory method exists for this scoring, it should be provided to ERIM for implementation, otherwise, some method must be devised and tested.

The input image frame-size is not a critical issue but could cause problems for the display software if it is not settled early. The scanner is line oriented and has no inherrant frame organization itself. However, several parts of the processing algorithms assume their input data is organized in a frame, or is derived from such image data. Unless some other considerations exist, the image frame-size should be a power-of-two fraction of the number of display lines. The most obvious candidates are 512 or 1024 lines per image. This choice will simplify any necessary image manipulation related to display operations as well as utilizing the full resolution of the DAP monitor.

A related display issue is scrolling vs. framing. There are several ergonomic issues involved and ERIM anticipates that a detailed study will be funded to resolve those. In addition there is a performance issue: the DAP attempting to implement a scrolling display. For a reasonable scrolling display, the image must be updated (scrolled) at faster than ten times a second, preferrably 30 times a second, to avoid flicker. Since no hardware scrolling is supported in the DAP display board, each update would require shifting the display image in the DAP memory, filling in the new lines on the bottom of the image, and copying the entire image to the display board. In addition, vertical decimation of the image (2:1 or more) may be necessary to avoid operator fatigue from viewing a fast-scrolling image. This could put a severe processing load on the DAP and could prevent it from completing other

required processing operations. Assistance from AMT will be necessary to determine if this is a serious problem.

Another display issue is the type of queues or tags to be overlaid on the operator's image to indicate mines. The tags must be large enough for the operator to see them, but also must not consume a large amount of DAP processing-time for their generation. The ergonomic questioned should be answered by the previously mentioned human-factors study. AMT assistance determining graphics processing operation times would be helpful to resolve this issue.

A final issue is the exact nature of the operator's input to the real-time processing operation. This issue was not addressed at all in the time-line of Figure 1, and no plan for resolving it has surfaced since the time-line was prepared. The main components of the problem are:

- What specific algorithm parameters will the operator be allowed to change during real-time operation;

- To what machine (DAP or Transputer) will the operator input data;

- How will the operator input be synchronized to image frames.

ERIM does not have clear answers to the above questions. Further interaction with WES and the algorithms is needed to resolve this issue.